Low Loss Tapered Fiber Waveguide Modulator for Crew Cognitive State Monitoring (CSM)

Completed Technology Project (2017 - 2018)

Project Introduction

Many crew-related errors in aviation and astronautics are caused by hazardous cognitive states including overstress, disengagement, high fatigue and ineffective crew coordination. Safety can be improved by monitoring and predicting these cognitive states in a non-intrusive manner and designing mitigation strategies. Measuring hemoglobin concentration changes in the brain with functional Near Infrared Spectroscopy (fNIRS) is a promising technique for monitoring cognitive state and optimizing human performance during both space and aviation operations. A compact, wearable fNIRS system would provide an innovative early warning system during long duration missions to detect and prevent vigilance decrements in pilots and astronauts. During FY17 a fNIRS device was designed and built at GRC for human flight simulator testing by LaRC beginning Nov 2018. This device uses a bulk modulator because of its higher efficiency and optical output. As a parallel effort, a waveguide modulator was also built which implemented the fNIRS modulation techniques in polarization-maintaining (PM) fiber-pigtailed waveguide form, which is necessary for the device to be miniaturized into a robust system for clinical and field use. But the 90% optical loss of commercial waveguide modulators reduces the optical output of the system below detection limits. The goal of this effort is to decrease the loss of the waveguide modulators from 90% to <10% by tapering PM optical fibers to better couple with the waveguide internal to the modulator, overcoming the intrinsic limiting factor on power throughput to obtain virtually lossless waveguide modulation. The compelling and motivating vision for modifying a Mach-Zehnder interferometric waveguide modulator in this manner is that it enables field-configurable fNIRS instrumentation without the need for the tedious and time-consuming optical alignment required by a bulk modulator. Investing in this effort will enable a working system prototype suitable for field use. This work will leverage prior Center Innovation Fund (CIF) fNIRS waveguide modulator research as well as the Vytran Fiber Processing Workstation obtained from the 2017 Laboratory Investment Fund (LIF). Final testing will be performed using a novel active phantom developed during our previous CIF award which simulates the optical properties of brain tissue combined with a circulating blood simulant. The goal is to enable a miniaturized, robust and easily configurable fNIRS unit required for field use by reducing waveguide modulator optical loss from current state of the art (SOA) 90% to less than 10%, reducing laser power and PMT requirements.

Anticipated Benefits

The technique under development applies to all waveguide modulators, regardless of wavelength, enabling application in many areas of NASA interest. The ability to monitor cognitive state in the field is equally needed in both space and aeronautics operations, anywhere safety-critical tasks have a human in the loop. Application in the telecommunications area would lead to huge savings by eliminating the need for large, expensive, and noisy optical

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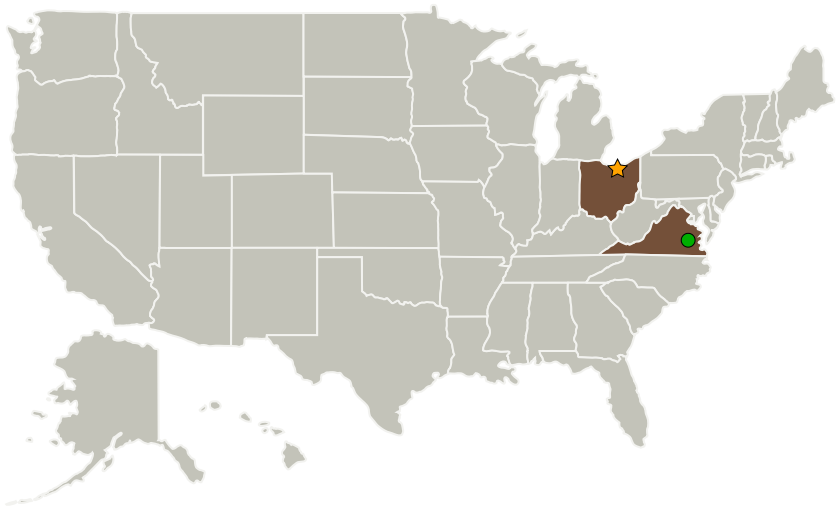
amplifiers. Applications in the medical and industrial fields include robust, compact, low-power rheological devices.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Glenn Research Center(GRC)	Lead Organization	NASA Center	Cleveland, Ohio
●Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Primary U.S. Work Locations	
Ohio	Virginia

Project Transitions

October 2017: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Glenn Research Center (GRC)

Responsible Program:

Center Innovation Fund: GRC CIF

Project Management

Program Director:

Michael R Lapointe

Program Managers:

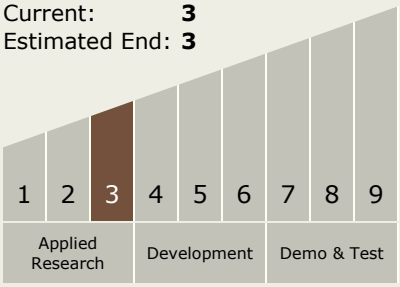
Kurt R Sacksteder
Gary A Horsham

Principal Investigator:

Joanne C Walton

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **3**



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September 2018: Closed out

Closeout Summary: The goal of this effort was to develop a process, independent of waveguide modulator wavelength, to reduce optical loss from current state of the art 90% to less than 10%, reducing laser power, photomultiplier tube requirements, and eliminating the need for large, expensive and noisy optical amplifiers. The current maturity is TRL 3. Modulators successfully modified using the technique under development can be used to replace the current bulk modulators in the GRC-built functional Near Infrared Spectrometer.

Project Website:

https://www.nasa.gov/directorates/spacetech/innovation_fund/index.html#.VC

Technology Areas

Primary:

- TX05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems
  - TX05.5 Revolutionary Communications Technologies
    - TX05.5.1 Cognitive Networking

Target Destination

Earth